

No part of the candidate's evidence in this exemplar material may be presented in an external assessment for the purpose of gaining an NZQA qualification or award.

SUPERVISOR'S USE ONLY

3

91523



Draw a cross through the box (☒) if you have NOT written in this booklet

+



Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 3 Physics 2025

91523 Demonstrate understanding of wave systems

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of wave systems.	Demonstrate in-depth understanding of wave systems.	Demonstrate comprehensive understanding of wave systems.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

Make sure that you have Resource Booklet L3-PHYSR.

In your answers use clear numerical working, words, and/or diagrams as required.

Numerical answers should be given with an appropriate SI unit.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–15 in the correct order and that none of these pages is blank.

Do not write in the margins (✂/✂/✂). This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Achievement

TOTAL 10

QUESTION ONE: THE DOPPLER EFFECT



<https://www.sea-doo.gr/blog/types-of-jet-skis/>

Martin and Kerry are riding their jet skis on a lake. Martin's jet ski is fitted with an air horn that emits a frequency of 1043 Hz . At one point, Kerry stops and Martin travels directly towards her at a speed of 27.3 m s^{-1} . The speed of sound in air is 343 m s^{-1} .

- (a) Calculate the frequency of the sound that Kerry hears.

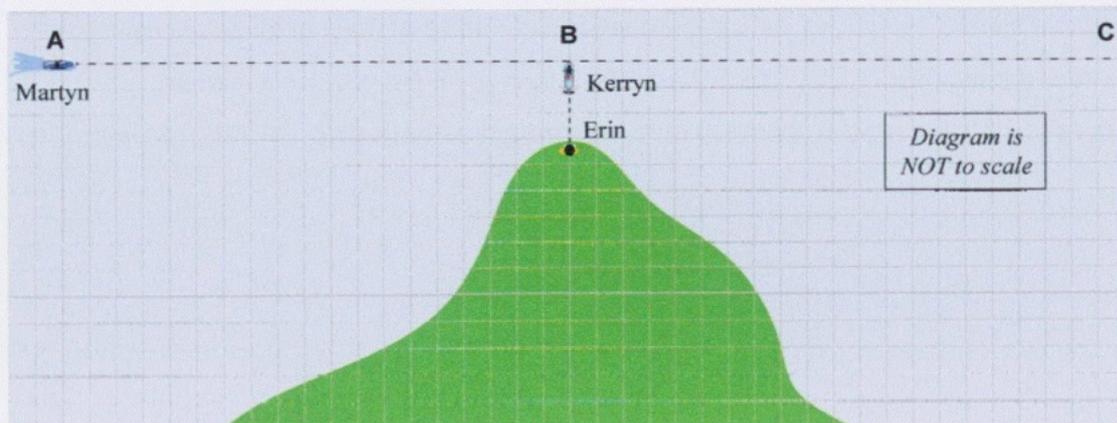
$$f' = f \frac{v_w}{v_w - v_s} \quad \cancel{f' = \frac{343}{343 - 27.3}} \quad f' = 1043 \times \frac{343}{343 - 27.3}$$

$$f' = 1133.19 \text{ Hz (rounded)}$$

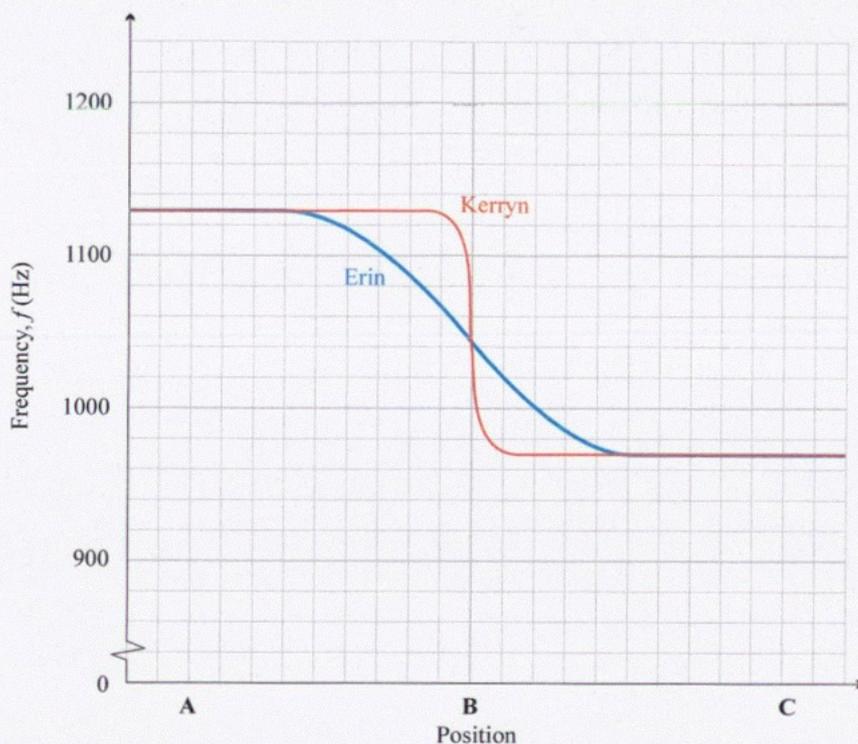
- (b) Explain why Kerry hears a different frequency than that emitted by the jet ski's air horn.

Kerry hears a different apparent frequency because the source of the horn is approaching her. This means the sound waves are becoming more compressed as it gets closer making the horn seem like it is sounding at a different frequency.

- (c) Kerry is floating very close to the path of Martin's jet ski, while her friend Erin is watching from a bank on the edge of the lake.



The graph shows the frequency of the sound heard by Kerryn and Erin as the jet ski travels from A to C.



Explain why the frequency that Kerryn hears is the same or different to that which Erin hears.

Kerryn at point B will have Martin pass by very closely before he starts to move on to point C. This can be seen in the very quick drop in frequency that Kerryn hears at point B. As soon as Martin passes Kerryn the frequency that she will hear will be significantly lower than the frequency (true) when Martin was right next to her. Erin standing on a bank will hear a different frequency to Kerryn as he is further away from where the jet ski (Martin) will pass by. This means that there will be a more gradual drop in the frequency that he will hear compared to Kerryn.

- (d) An underwater microphone has been submerged in the lake to monitor noise pollution from jet ski engines. Martyn's jet ski engine makes a sound at 574.0 Hz . As the jet ski travels away from the underwater microphone at 27.3 m s^{-1} , the microphone measures a frequency of 563.6 Hz coming from the jet ski engine.

Calculate the velocity of sound in water.

$$f' = f \times \frac{v_w}{v_w + v_s}$$

$$563.6 = 574 \times \frac{v_w}{v_w + 27.3}$$

$$v_w = x$$

$$563.6 = 574 \times \frac{x}{x + 27.3}$$

$$x = 1479.45$$

$$v_w = 1479.45 \text{ m s}^{-1}$$

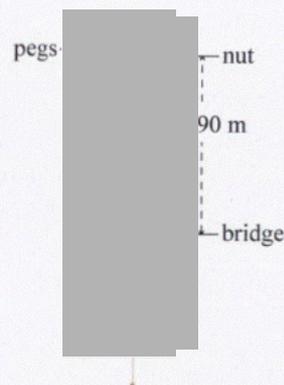
QUESTION TWO: STANDING WAVES

The cello is a stringed instrument belonging to the violin family.

The strings are supported at each end by a piece of wood called the bridge and the nut respectively.

The length of the strings between the supported ends is 0.690 m.

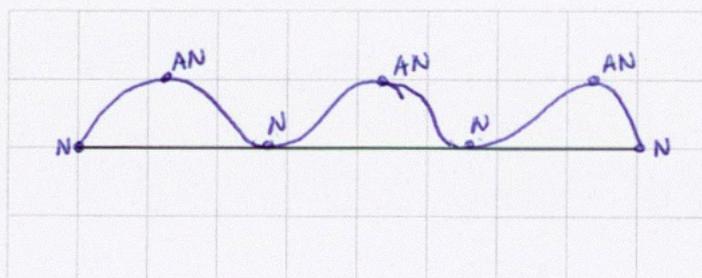
When the cello is played, the strings can vibrate in different harmonics.



Source: https://en.wikipedia.org/wiki/Cello#/media/File:Cello_front_side.png

- (a) Draw a diagram of the 4th harmonic.

Label the nodes and antinodes.



AN = Antinode
N = node

If you need to redraw your response, use the diagram on page 11.

- (b) Sometimes if the cello has been in storage, the tension in the strings will decrease, and the instrument will be out of tune. The strings will therefore play a frequency that is other than the desired frequency. *

Use the equation below to explain how this could have caused the frequency to be higher or lower than the desired frequency.

$$v_{\text{wave on string}} = \sqrt{\frac{\text{tension}}{\text{mass per unit length}}}$$

No calculations are required.

If in storage the tension loosens/decreases using this equation, that reduction has a direct impact on the velocity of the wave and therefore combined with the reduction in mass per unit length the frequency emitted will be lower than the desired frequency.

- (c) When a 0.690 m string is played, the first harmonic has a frequency of ^{N₁}147 Hz. A finger is then pressed onto the string, changing the length of the string to play a first harmonic with a frequency of 207 Hz.

Calculate the new length of the string when the second note of 207 Hz is played.

Assume that the tension in the string remains constant.

$$\lambda = 2L \quad v = f\lambda$$

$$2 \times 0.690 = 1.38$$

$$v = \cancel{138} \times$$

$$v = 147 \times 1.38 \quad 202 = 207 \times x$$

$$v = 202 \quad x = \lambda \quad \lambda = 0.976$$

$$\lambda = 2L$$

$$\lambda/2 = L$$

$$\cancel{L = 0.49m} \quad L = 0.488m$$

- (d) Two strings that are next to each other can be played at the same time. When string 2 is played (without a finger being pressed on it), it produces a note with a frequency of 98.0 Hz. Strings 1 and 2 are played at the same time that a finger is pressed onto string 1, and the length of string 1 is gradually reduced until a beat is heard.

- (i) Explain why beats form.

~~Beats form at points of constriction~~
 Beats form when the waves are out of sync so when the trough of string 1 occurs string 2 will be at its peak amplitude this occurs when 1 wave is half the size of the other



- (ii) Explain what will be heard as the length of the string continues to be gradually reduced.

The velocity of the wave will decrease as the v is a product of the $f \times \lambda$ this also means that if the wavelength is $2L$ and L is being reduced the wavelength will also decrease, This means the frequency heard will stay the same.

QUESTION THREE: INTERFERENCE PATTERNS

A laser shines green light onto a double slit, which has a slit separation of 1.25×10^{-4} m. Each slit then acts as a light source that is in phase, producing an interference pattern on a screen with fringes that are close together.



Diagram is
NOT to scale

Source: <https://courses.lumenlearning.com/suny-physics/chapter/27-3-youngs-double-slit-experiment/>

When the screen is 3.40 m from the slits, the distance from the central maxima to the 3rd order maxima is 4.20×10^{-2} m.

- (a) Show that the laser has a wavelength of 515 nm.

$$n\lambda = \frac{d\alpha}{L}$$

$$\lambda = \frac{1.25 \times 10^{-4} \cdot 4.70 \times 10^{-2}}{3.40}$$

$$\lambda = 5.15 \times 10^{-7} \text{ m} = 515 \text{ nm}$$

- (b) Explain why the intensity of the light on the screen varies, as shown.

2 slits



Because as the light is shone through by the laser it refracts forming standing waves. This pattern of intensity on the screen shows bright fringes which is the product of constructive interference when the wave is in sync and dark fringes when the waves are out of sync = points of destructive interference.

- (c) The double slit is replaced with a diffraction grating which has more closely-spaced slits.

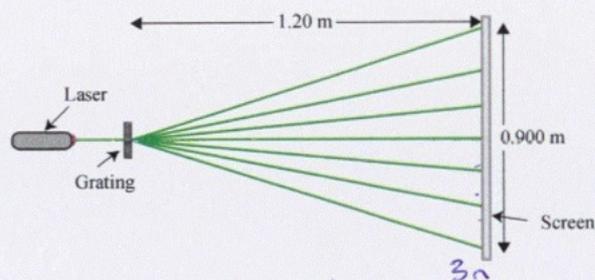
Describe and explain the changes to the interference pattern observed on the screen.

If the double slit was replaced with a diffraction grating there would be a very different pattern as there would be more points of destructive and constructive interference.

There would also not be a central maxima that is the brightest fringe as not all the waves would cross forming that instead the middle would be none to the darkest central fringe where the most destructive interference occurs.

Question Three continues
on the following page.

- (d) In another experiment, a green laser, of wavelength 515 nm, is shone through a different diffraction grating and 7 maxima are seen on the screen. The screen is 0.900 m wide and is 1.20 m from the diffraction grating.



Calculate the possible range of values for the slit separation of the diffraction grating.

$$n\lambda = \frac{d\alpha}{L}$$

α = central maxima to 3rd order

$$0.900 \div 2 = 0.45$$

$$\alpha = 0.45 \quad \leftarrow = d$$

$$3 \times 515 = \frac{3 \times 0.45}{1.20}$$

$$3 \times 5.15 \times 10^{-7} = \frac{\alpha \times 0.45}{1.20}$$

$$3n \quad d = 4.12 \times 10^{-4}$$

$$2n \quad d = 2.75 \times 10^{-4}$$

$$1n \quad d = 1.37 \times 10^{-4}$$

(all rounded)

Achievement

Subject: L3 Physics

Standard: 91523

Total score: 10

Q	Grade score	Marker commentary
One	3	<p>In (b), the candidate needed to specify increase or decrease, rather than “different” and only restated the information given in (c). In (d), insufficient working was shown for a full grade.</p>
Two	4	<p>In (a), the wave is not centered on a stationary string at the equilibrium position. The distances between nodes and antinodes are not equal.</p> <p>In (b), the candidate needed to specify an increase or decrease in velocity rather than state it was different and mention that the wavelength is constant.</p> <p>In (c), a more logical and sequential progression with formulae and layout would have improved the grade.</p> <p>In (d)(i), the candidate has poorly described the phase and resulting interference and neglected to link this to the resulting volume or mentioned the alternating volume. In (d)(ii), the candidate has incorrectly assumed that changing the length of the string changes the velocity, and there is no mention on the effect to the beat frequency.</p>
Three	3	<p>In (a), the candidate has given the correct answer and identified in (b) that constructive interference causes a bright region. They did not however specify that this occurs when the waves are in phase, due to a path difference of a whole number of wavelengths (and likewise for destructive interference being due to the waves being out of phase when the path difference is odd multiples of half wavelengths).</p> <p>In (c), the candidate has not identified any of the changes to the pattern and incorrectly discusses “more points” of constructive interference. The candidate has identified that the 3rd order fringe is observed on the screen in (d), but used the small angle approximation formula for a large angle. The candidate does not identify that the edge of the screen is between the 3rd and 4th fringe.</p>